LETTERS TO THE EDITOR.

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The Analogy between Radicles and Elements.

THE remarkable chemical analogy of the ammonium radicle and the alkali metals may be explained with the help of Bohr's theory of atomic structure. According to Bohr, the atom of nitrogen consists of a nucleus with a positive charge of $7e$, surrounded by two rings of electrons, the inner containing 4, the outer 3 electrons. N is, therefore, represented by 7 (4, 3). Ordinary chemical compounds are supposed to be held together by rings of electrons rotating in planes perpendicular to the lines connecting the nuclei of the composing atoms; so that NH_3 may be represented by (4, 3 − 3). This principle leads, however, to difficulties, if applied to NH_4; a configuration (4, 3 − 4) seems impossible. It is better to suppose the nuclei and electrons to rearrange themselves within the atom. I assume, therefore, that the nuclei unite, or at least that they get quite close to each other, in the centre of the system, while the electrons arrange themselves in four rings (4, 4, 2, 1), rotating round the joined nuclei. It may seem difficult to bring the nuclei together against the repelling forces, but it must be remembered that the radicle NH_4 can only be formed by indirect methods; in no circumstances will ammonia and hydrogen unite to form NH_4. The co-operation of another molecule containing hydrogen, like H_2O, HCl, is absolutely necessary, an intermediate compound first being formed, from which the ammonium-ion is produced by electrolytic dissociation. Once liberated, the ammonium decomposes immediately; it is extremely unstable, exactly conforming to our expectations. It is also important to remark in this connection, that, according to Coehn, electric charges are given off during the decomposition.

The arrangement proposed at once shows analogies with Bohr's representation of Na (8, 2, 1) and K (8, 8, 2, 1). These two configurations contain the same outer rings as NH_4 and differ only with regard to the inner rings. The number of electrons in Na and NH_4 is even the same; in K and NH_4 we find the same number of rings. The second similarity seems to be of primary importance, ammonium resembling potassium more closely than sodium. The fact that the analogy does not go further than the chemical properties follows at once from the general principle that the chemical character of a substance depends only on the outer rings.

The same considerations apply, of course, to PH_4, which, however, is only known as an ion, and AsH_4, and perhaps to hydrazine, which shows some resemblance to calcium. Whether the substituted ammonium bases may also be drawn within their scope is not yet settled.

There is still another line of thought to which I wish to direct attention. In the periodic table nitrogen is placed in the fifth group. When it combines with four hydrogen atoms, according to the above hypothesis, the nucleus charge increases by $4e$; the resulting radicle is analogous to a metal of the first group, *i.e.* to an element which occupies the *fourth* place on the right of the original element. This is exactly the reverse of the radio-active transformations in which by the loss of an α particle ($2e$) the atom removes two places to the left.

This idea may also be applied to the analogous sulphur and iodine bases. Although these are only known in compounds, in which the hydrogen atoms are substituted by aliphatic or aromatic radicles, we shall take for discussion the fundamental types; instead of SR_3OH and IR_2OH, we consider the radicles SH_3 and IH_2. SH_3 also has the chemical properties of an alkali metal. Now, sulphur is placed in the sixth group; if the nucleus takes up three elementary charges, $3e$, the atom shifts its position by *three* places to the right, and arrives in the first group, thus confirming the general law. Also, the change of the iodine atom (seventh group) by taking up two hydrogen atoms, $2e$, is an agreement with the theory, for the iodonium radicle also exhibits the properties of a strong base. Iodonium, it is true, especially resembles thallium, but it is known that thallium and silver are closely similar; so iodonium also fits in the first group.

The above considerations may be extended to cyanogen and the halogens, which also show a striking resemblance. Though cyanogen is not unstable, it is not easily obtained. Its formation is only possible at high temperatures, and in the presence of alkalis, or by the use of electric discharges. It is a strongly endothermic compound. The structure of the CN radicle may be represented by 13 (4, 4, 4, 1), whilst Bohr writes fluorine 9 (4, 4, 1), and chlorine 17 (8, 4, 4, 1).

E. H. BUCHNER.

Chemical Laboratory, University of Amsterdam,
July, 1915.

The Density of Molecules in Interstellar Space.

IN recent years evidence has been brought forward by several investigators[1] indicating that light from distant stars suffers a slight attenuation in travelling through interstellar space. In particular a recent investigation by Jones[2] assigns fairly definite numerical values to coefficients of attenuation corresponding to "photographic" and "visual" light from stars of known proper motions and spectral types the magnitudes of which had been carefully measured by Parkhurst[3] for light of these wave-lengths. If, as seems reasonable, this extinction is assumed to be due to attenuation by scattering in travelling through a "residual" gas occupying interstellar space, we are enabled to estimate the average density of molecules in the intervening regions, following a method due originally to Larmor[4] for assigning an upper limit to the density of matter in comets' tails.

If we denote by κ the coefficient of attenuation corresponding to wave-length λ, radiation of this wave-length originally of intensity E_0 is reduced, after travelling a distance x, to the value given by $E = E_0 e^{-\kappa x}$. According to Rayleigh's law of molecular scattering, κ is given in terms of the refractive index μ, and the molecular density of the medium n by the relation $\kappa = \frac{8}{3}\pi^3(\mu^2 - 1)^2\lambda^{-4}/n$. The ability of Rayleigh's law to account almost completely for the attenuation of solar radiation in travelling through the earth's atmosphere was first pointed out by Schuster[5]; a later investigation by the writer,[6] based on the results of the Smithsonian Astrophysical Observatory, indicated that formulæ based on this law were competent to explain atmospheric extinction as well as to account quantitatively and qualitatively for the intensity and distribution of sky-radiation as far as the observations available at that time could be tested. As a final test, the Smithsonian results were reduced with a view to obtaining a value for the number of molecules per cm.^{3} of a gas at standard temperature and pressure; the result obtained by the writer,[7] $n_0 = (2{\cdot}78 \pm 0{\cdot}01) \times 10^{19}$, and a later independent determination by Fowle,[8] $n_0 = (2{\cdot}70 \pm 0{\cdot}02) \times 10^{19}$, indicate that we may rely with confidence on Rayleigh's law in dealing with molecular extinction for wave-lengths not too close to regions of selective absorption.

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[1] Kapteyn, J. C., *Astrophysical Journal*, xxix. (1909), pp. 46–54: xxx. (1909), pp. 284–317 and correction p. 398. Turner, H. H., *Monthly Notices* Roy. Ast. Soc., lxix. (1908), p. 61. King, E. S., *Harvard Annals*, lix., No. 6, p. 179, April, 1911; *Harvard Annals*, lxxvi., No. 1, pp. 1–10. 1913. Brown, F. G., *Monthly Notices*, lxxii. (1912), p. 195, also p. 718.

[2] Jones, H. S., *Monthly Notices* Roy. Ast. Soc., lxxv (1914), pp. 4–16.

[3] Parkhurst, J. A., "Yerkes Actinometry," *Astrophysical Journal*, xxxvi. (1912), p. 169.

[4] Larmor, Sir J., Lectures, Cambridge, 1908.

[5] Schuster, A., NATURE, July 22, 1909; "Optics," 2nd Edition, 1909, p. 329.

[6] King, L. V., Phil. Trans. Roy. Soc., ccxii. A (1912), pp. 375–433.

In dealing with attenuation in a stellar distance $x = \Delta$, the term $\kappa\Delta$ is so small that we may write to sufficient degree of approximation $\kappa\Delta = (E_0 - E)/E_0$, *i.e.* $\kappa\Delta$ is the proportional loss of intensity in travelling a distance Δ. Denoting by $\kappa_1\Delta$ and $\kappa_2\Delta$ the proportional losses of intensities corresponding to "photographic" and "visual" light of average wave-lengths λ_1 and λ_2 respectively, we derive on reducing to intensities the result obtained by Jones,[9] [(photographic)−(visual)] losses $= +0{\cdot}00473 \pm 0{\cdot}00035$ magnitude, the relation $(\kappa_1 - \kappa_2)\Delta = 0{\cdot}00435 \pm 0{\cdot}00032$, the distance Δ being 10 parsecs (1 parsec = distance corresponding to a stellar parallax of $1'' = 3{\cdot}26$ light-years $= 3{\cdot}08 \times 10^{19}$ cm.). If it is assumed that the extinction is brought about solely by molecular scattering, we also have the additional equation $\kappa_1/\kappa_2 = (\lambda_2/\lambda_1)^4$.

Unfortunately, it is somewhat difficult to assign with accuracy the average wave-lengths corresponding to "photographic" and "visual" light. A rough estimate by the writer from Parkhurst's curves of spectral intensities corresponding to the plates and filters employed in the photographic and visual determinations yielded the values $\lambda_1 = 0{\cdot}446\mu$ and $\lambda_2 = 0{\cdot}533\mu$, so that we obtain $\kappa_1/\kappa_2 = 2{\cdot}08$, giving $\kappa_1\Delta = 0{\cdot}0083_8$ and $\kappa_2\Delta = 0{\cdot}0040_3$.[10] In order to realise more vividly the extremely small attenuation which these numbers represent, it is easily verified that in order to lose one-tenth of its original intensity radiation of these wave-lengths must travel for about 4·1 and 8·5 centuries respectively.

For the purposes of the present discussion we assume hydrogen to be the constituent of interstellar space (until we know more about the physical properties of "coronium," "nebulium," or other primordial gases which might possibly occupy these regions). Taking $\mu_0 - 1 = 0{\cdot}000140$, $n_0 = 2{\cdot}78 \times 10^{19}$, $\lambda = 4{\cdot}46 \times 10^{-5}$ cm., we easily derive for the coefficient of attenuation in hydrogen at standard temperature and pressure the value $\kappa_0 = 5{\cdot}89 \times 10^{-8}$ cm.$^{-1}$. For this wave-length in interstellar space we have $\kappa = 2{\cdot}72 \times 10^{-22}$ cm.$^{-1}$, so that $n/n_0 = \kappa/\kappa_0 = 4{\cdot}62 \times 10^{-15}$, giving finally for the molecular density in interstellar space the estimate $n = 1{\cdot}28 \times 10^5$ hydrogen molecules per cm^3.[10]

Associated with the problem of attenuation by scattering is that of calculating the amount of starlight scattered by the molecules of interstellar gas.[11] In this way might be explained the extremely faint luminosity which several observers believe to exist over the background of the sky. This scattered light might also account for discrepancies which have been found to exist between calculated and observed distributions of total starlight from different regions of the night sky.[12] The estimation of the amount of solar radiation scattered to the earth by a distribution of interstellar gas constitutes a definite problem, the complete statement of which (including the effect of self-illumination) is expressed as a particular case by a general integral equation already given by the writer.[13] The theoretical discussion applicable to the problem under discussion the writer hopes to undertake elsewhere; from the observational point of view it would seem that the difficult, but perhaps not impossible, task of estimating the luminosity of the sky in regions void of stars affords the only hope of bringing additional direct evidence to bear on some of the questions raised below.

In a gas of the extreme degree of tenuity which we have just estimated, molecular collisions will be extremely infrequent; an estimate of the free path, according to the usual ideas of the kinetic theory, is impossible without a knowledge of the average molecular velocity or temperature of the gas. As has already been pointed out by the writer,[14] it is difficult to see how molecular velocities can be directly affected by radiation travelling through a gaseous medium. It is probable that gravitation and radiation-pressure are the controlling forces in determining molecular velocities by an extremely slow process of equipartition of energy with that of molecules escaping from planetary and stellar atmospheres.

As the above estimate of molecular density gives a total amount of matter of the order 1/38 × earth's mass in a sphere having a radius equal to that of Neptune's orbit, it is improbable that the residual gas we are considering could have a noticeable effect on planetary motions. It might, however, be identified with the slightly resisting medium the existence of which has been thought necessary by some astronomers to account for the secular acceleration of Encke's comet,[15] and which is considered by See[16] to have played an important *rôle* in planetary and stellar evolution.

The molecular density estimated above is very much less than that conjectured to exist in some of the nebulæ, 10^9 molecules per cm.^{3} being about the order of magnitude in this case.[17] While the degree of rarefaction which we have derived is very much greater than it is possible to produce by any known physical means,[18] the total amount of matter contained in regions of space of astronomical dimensions is formidable; thus we find for the number of molecules in a cubic parsec the estimate $N = 3{\cdot}75 \times 10^{60}$ hydrogen molecules per parsec^3. Taking the density of hydrogen at standard temperature and pressure to be 0·0899 gramme per litre (containing $2{\cdot}78 \times 10^{22}$ molecules), we obtain for the density of matter in interstellar space the estimate $1{\cdot}21 \times 10^{37}$ grammes per parsec^3; as the sun's mass is approximately $1{\cdot}96 \times 10^{33}$ grammes, we have finally for the density of interstellar residual gas the estimate $6{\cdot}3 \times 10^3$ sun's mass per parsec^3. According to Eddington,[19] a reasonable

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[7] King, L. V., NATURE, xciii. (July 30, 1914), pp. 557–559.

[8] Fowle, F. E., *Astrophysical Journal*, xl. (December, 1914), pp. 435–442.

[9] Jones' determination is in fair agreement with Kapteyn's final result, (*Astrophysical Journal*, xxx, p. 398):

$$[(\text{photographic})-(\text{visual})] \text{ losses} = +0^{m}{\cdot}0031 \pm 0{\cdot}0006.$$

The corresponding determinations by King (E. S.) of the coefficients of attenuation for photographic and visual light give values about five times that of the text.

[10] The losses $+0^{m}{\cdot}0080$ and $+0^{m}{\cdot}0033$ estimated by Jones for "photographic" and "visual" light lead to the values $K_1\Delta = 0{\cdot}0073$ and $K_2\Delta = 0{\cdot}0030$ (wave-lengths not stated). Kapteyn's (corrected) estimate for wave-length $\lambda_1 = 0{\cdot}431\mu$ is $K_1\Delta = 0{\cdot}00507$, leading to the value $n = 0{\cdot}68 \times 10^5$ hydrogen molecules per cm.^{3}, which is of the same order of magnitude as the determination already made. E. S. King's results (footnote 1) increase the estimate of the text about five-fold.

[11] Note a discussion on this point by H. C. Plummer in a paper by H. H. Turner, *loc. cit.* (footnote 1).

[12] Abbot, C. G., *Astronomical Journal*, xxvii. (1911), p. 20; "Annals of the Smithsonian Astrophysical Observatory," vol. iii. (1913), pp. 203–210.

[13] King, L. V., footnote (6), p. 379, equation (14).

[14] King, L. V., footnote (7).

[15] On the recent history of this comet see a paper by Backlund, "Encke's Comet, 1805–1908," *Monthly Notices*, lxx. (1910), pp. 429–442.

[16] See, T. J. J., "Researches on the Evolution of the Stellar System," 1910, vol. ii., pp. 134–158.

[17] Henkel, F. W., in an article "Nébuleuses et Essaims," *Scientia*, vol. xv. (1914), pp. 294–307.

[18] The total number of molecules per cm.^{3} corresponding to the vapour-pressure of mercury at the temperature of liquid air is estimated at 3×10^7 (Dunoyer, M. L., "Les Gaz ultra-raréfiés," in the collection "Les Idées Modernes sur la Constitution de la Matière," Paris, Gauthier-Villars, 1913, p. 216).

[19] Eddington, A. S., "Stellar Movements and the Structure of the Universe." Macmillan and Co., Ltd., 1914, p. 255.

estimate of the density of visible stars in the neighbourhood of the solar system is $10 \times$ sun's mass in a sphere of 5 parsecs radius (525 parsec^3), *i.e.* $0{\cdot}019 \times$ sun's mass per parsec^3. It follows that the density of "uncondensed" or "residual" matter existing in interstellar space is of the order 10^5 that of "condensed" stellar matter. Even if, as there is some reason to believe, the number of "dark" stars is very much greater than the number of bright ones (Lindemann's estimate is 4000),[20] the ratio referred to is still very large.

It is evident that unless this "residual" or "primordial" gas is exempt from mutual gravitation[21] it must give rise to a gravitational field very much greater than that of the whole sidereal universe, and should therefore be taken into account in existing theories of stellar dynamics. Although the dynamics of such a system would probably have to be modified to a considerable extent to take into account radiation pressure, we should still expect an enormously high density near its mass-centre, unless the whole be endowed with a small angular velocity, as is surmised to be the case with the Milky Way.

It follows from this brief discussion that we are either obliged to accept the existence of a widespread distribution of enormous quantities of interstellar gas of molecular density of the order 10^5 molecules per cm.^{3} and take into account its influence in stellar dynamics, or conclude that the attenuation of light by scattering is very much less than is indicated by existing estimates of the absorption of stellar radiation in space.

Louis Vessot King.

McGill University, Montreal, June 30, 1915.

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[20] Lindemann, F. A., "Note on the Number of Dark Stars," *Monthly Notices*, lxxv. (1915).

[21] On this point note a remark by Eddington, *loc. cit.*, p. 258.

The Great Aurora of June 16, 1915.

In reply to Dr. Chree's note in Nature for July 22 concerning the auroral display of June 16, I would say that the times (as indicated in my note in Nature for July 15) were in Greenwich Mean Time. This, of course, begins at Greenwich Mean Noon. It did not occur to me that this might be misleading to the unastronomical reader. If one will subtract twelve hours from the times given by me, he will then have the dates for the morning of June 17 at Greenwich. Thus June 16d. 15h. 30m. G.M.T. will be June 17d. 3h. 30m. a.m., Greenwich Civil Time.

I will take the opportunity to quote here from the Los Angeles (Cal.) *Tribune* of June 18, 1915, a despatch from Chicago dated June 17:—

"Chicago telegraph operators were puzzled to-day when their wires failed at times to work. Soon, however, the explanation of the trouble came. It was not due to power stations or lack of current, but to the aurora borealis.

"The bewildering beauty of the northern lights lighted up all of Canada and the north-western part of the United States last night and caused electrical disturbances that put telegraph wires entirely out of commission in Idaho, Montana, and the Dakotas and along the Canadian Pacific railroad.

"The disturbances extended to Chicago to-day and to-night, and reports of trouble between Pittsburgh and New York, St. Louis and Kansas City, and many other cities over the country, were received. Operators here stated to-night that the disturbance was the worst they had known in five years.

"W. F. Weber, wire chief for the Western Union, reported service considerably demoralised.

"'Our wires the whole length of the land were badly affected early to-day,' he said. 'They are affected still, though not to such a degree. The disturbance of the atmosphere causes fluctuation of the current on the wires, and interferes with rapid transmission of signals. We have been obliged to operate at a much lower speed than normal to-day.'

"The Postal Telegraph Company was similarly affected.

"It also was reported that train-dispatching on the Canadian Pacific railroad virtually ceased for several hours. Similar conditions prevailed on other northern transcontinental lines."

E. E. Barnard.

Yerkes Observatory, Williams Bay, Wisconsin,
August 4.

Use of Celluloid in Periscope Mirrors.

I should be glad to know, in reference to the possibilities of diminishing the danger in using periscopes under fire: (1) whether experiments have been tried as to the effect of cementing a plate of celluloid to the back of the exposed mirror in preventing or reducing the splintering of the glass when struck by a bullet, and, if so, with what result; (2) whether there is any danger involved in the use of celluloid for this purpose?

Edward M. Langley.

48 Waterloo Road, Bedford, August 17.

Foreign Philosophers.

One of the original objects of our Association for the Advancement of Science was to encourage the exchange of ideas with foreign philosophers, *vide* First Report of B.A. This year it will be a disappointment to many people in Manchester to have so few distinguished strangers. We now call them prisoners of war or alien enemies. But they still wish for scientific enlightenment.

Inquiries made in the prisoners' camp at Stobs reveal a small library carefully catalogued. They have some hundreds of English books, including some scientific books; also, in German, Schiller and Goethe. They ask particularly for Naturwissenschaft in Deutsch, Chemie, Physik, Geologie, Botanik, also agriculture (Landwirthschaft), navigation, engineering, mathematics, mathematical astronomy for seamen, logarithms, Electrotechnik. There are repeated inquiries for a German book on spherical trigonometry, enough copies for the navigation class.

The requests we have the honour to transmit may be satisfied by sending books direct to Von Vorman, Librarian, Prisoner of War, Hut 18, Compound A, Stobs, near Hawick, Scotland. Inquiries as to books likely to be welcome in other camps may be addressed to the Emergency Committee, 169 St. Stephen's House, Westminster Bridge, S.W.

Some of the prisoners have already expressed a general willingness to remind their friends in Germany (with whom they are privileged to communicate) that the English prisoners in German camps are also asking for books.

Books sent by passenger train should be carriage paid, by parcels post they go free of charge.

August, 1915. Hugh Richardson.

French Magnanimity.

French history furnishes an interesting parallel to the magnanimity shown by Napoleon to the University of Pavia referred to in your issue of July 15. When Rudyerd was engaged in building the second Eddystone Lighthouse a French privateer captured some of his workmen and carried them prisoners to France. Louis XIV., however, as soon as he heard of it, put the captain and crew in prison, released the workmen, loaded them with presents, and sent them home, saying that though he was at war with England, he was not at war with mankind.

Gordon D. Knox.

11, Garrick Street, W.C., August 17.